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W. B. BIZZELL, President

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DIVISION OF PLANT PATHOLOGY AND PHYSIOLOGY

DISEASES OF GRAINS, SORGHUMS, AND MILLET, AND THEIR CONTROL IN TEXAS

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COLLEGE STATION, BRAZOS COUNTY, TEXAS.

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DISEASES OF GRAINS, SORGHUMS AND MILLET, AND THEIR CONTROL IN TEXAS.

BY

J. J. TAUBENHAUS

INTRODUCTION

Almost everyone thinks of Texas as being primarily a cotton State; therefore, the importance of the cereal crops is generally underestimated. According to the Monthly Crop Report* of the United States Department of Agriculture, the total area in 1918 devoted to the cereal crops in Texas was estimated at 10,603,000 acres and worth on the farm $195,548,200. On the other hand, the cotton acreage for 1918 in Texas was estimated at 11,283,000 acres and worth on the farm $380,215,000. Hence, we see that in 1918, the acreage and the money value of cotton were large when compared to the acreage and money value of the grains. This, nevertheless, forcibly emphasizes the importance of the cereal crops in Texas. It is staggering if we but realize the yearly losses to these crops from plant diseases. This is well shown in Table 1.

In carefully studying Table 1 we see that in 1918, which was practically a dry year, and in which the diseases of the cereal plants were but slightly prevalent in Texas, a large percentage of all the grain crops was lost solely on account of plant diseases. This, of course, does not include the losses from insect pests. Such a loss is staggering if we realize that it represents a direct waste of $21,641,461. As further indicated in Table 1, most of these losses could be reduced to a minimum. It is hoped that the information here presented with figures which speak but very conservatively, points the way to a saner and better agriculture, by indicating methods which, if intelligently carried out, will reduce the losses of the crops here considered to a minimum. Instead of an annual outright loss of $21,641,461 from diseases, the losses from plant disease may, through careful seed selection, seed treatment, and cultural methods be reduced materially. To effect this saving, the expense for labor and formaldehyde liberally estimated would be $5,000,000. Progressive farmers will not be slow in recognizing this fact.

The losses to the grains and cereal crops in Texas are due to plant diseases, for it has been definitely proved that diseases in plants are induced by bacteria or fungi. These are low forms of plant life and can only be seen when magnified under the microscope. It certainly will be to the advantage of every farmer to acquire a practical knowledge of the diseases covered in the present bulletin. Such a knowledge will insure the carrying out of control methods intelligently and effectively.

*Monthly Crop Report. December, 1919. Washington, D. C.

Table 1.—Losses from Cereal Diseases in Texas in 1918.

Kind of Crop	Total Acreage	Total Yield in Bushels or Tons	Total Value in Dollars	Kind of Diseases	Percentage of Loss	Loss Estimated in Dollars	Preventable Diseases
Corn	6,500,000	65,000,000 bu.	$ 114,400,000	Smut	8.00	$ 9,152,000	Only partly
				Leaf Rust	0.50	572,000	Only partly
				Physoderma	0.50	572,000	Only partly
				Root and Ear Rots	5.00	5,720,000	Only partly
Wheat	900,000	9,000,000 bu.	19,350,000	Bunt	0.50	96,750	Totally controlled
				Loose Smut	0.70	135,450	Totally controlled
				Scab, Stem Rust, Anthracnose	1.00	193,500	Partly controlled
Rye	4,000	22,000 bu.	51,700	Smut	0.50	258	Totally controlled
				Ergot	0.10	51	Totally controlled
Barley	10,000	170,000 bu.	221,000	Loose Smut	3.00	6,630	Totally controlled
				Covered Smut	5.50	12,155	Totally controlled
				Other diseases	1.00	2,210	Partly controlled
Oats	1,510,000	22,197,000 bu.	20,421,000	Loose and Covered Smut	8.50	1,735,805	Totally controlled
				Other diseases	1.00	204,212	Partly controlled
BroomCorn	74,000	19,200 T.	4,992,000	Head Smut	3.00	149,760	Cannot be control'd
Grain Sorghum	1,605,000	24,075,000 bu.	36,112,500			1,083,375	
				Kernel Smut	4.00	199,680 1,444,500	Totally controlled
				Other diseases	1.00	361,125	Partly controlled
Total	10,603,000	19,200 T. 120,464,000 bu.	$ 195,548,200	....	....	$ 21,641,461	

The present bulletin has been prepared as far as was consistent in a non-technical language and it is hoped it will meet the great demand for information on this subject. Full directions for sending in diseased specimens will be found on p. 33. The writer wishes also to acknowledge his indebtedness to Professor A. H. Leidigh, Agronomist of this Station, for helpful suggestions in reading the manuscript; and to Professor H. S. Jackson of Purdue University, for identification of *Puccinia purpurae*.

DISEASES OF WHEAT

STINKING SMUT (COVERED SMUT), OR BUNT

Caused by *Tilletia levis* Kuehn

Bunt is one of the serious wheat diseases in Texas, being more or less prevalent in the "Panhandle." The annual losses from this disease are rather small when compared to losses from loose smut. It is necessary to describe this disease in order that one may understand the correct method of combating it.

Symptoms. As a rule the disease does not become noticeable in the field until the wheat heads have reached full development. At that time, infected heads appear dark green to bluish in color and seem to mature later than the normal ones. This, however, is not a sufficient guide, and unless it is carefully looked for, bunt may escape the attention of the inexperienced. A close examination will reveal the fact that diseased heads remain erect and are slender, while those which contain sound grains become heavy and bend more or less from their own weight (Fig. 1, a).

In Northwest Texas, Turkey-type wheat ripens upright and does not "nod." Here the bunted heads are easily recognized jnst before fully ripe, because of the enlarged grains which seem to give a distended or "fat" appearance to the head, and the beards seem to stand out at a great angle. If one will examine a diseased head, it will be seen that its grains are larger but lighter than the grains of a healthy head (Fig. 1, b and c), and may be crushed with the slightest pressure of the fingers. When such a grain is crushed, its outer cover will break open and a dark-colored, ill smelling dusty snbstance will be liberated. The odor of bunt is disagreeable and very characteristic. Ordinarily, infected grains do not burst open in the field, they do so, however, during harvesting and threshing.

Life Cycle of the Bunt Fungus. It has already been mentioned that during threshing, the grains in the infected heads break open, thus liberating the fungus spores (Fig. 1, d), which adhere to the sound and normal kernels. When these kernels are planted and as soon as germination starts, the adhering fungus spores of bunt germinate, too (Fig. 1, e to g), and penetrate the young sprouting seedlings. Growth of the fungus then proceeds in the interior of the wheat plant and keeps pace with it until blossoming. The fungus then establishes itself in the ovaries of the wheat head, and prevents the formation of sound kernels by using up their entire contents and transforming them into smutty masses made up mostly of the spores of the causal organism.

It is believed that the spores in the spore balls of stinking smut when unbroken, may live from seven to eight years. On the other hand, when loose, they may live only about three years. As far as is known, bunt attacks wheat only. For methods of control, see p. 30

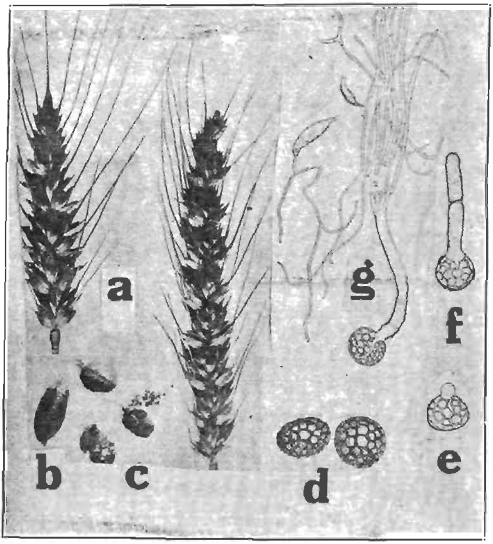

FIGURE 1.

a. Stinking smut (bunt) of wheat. To the right, healthy heads; to the left, diseased heads. b. Healthy wheat grain. c. Three wheat grains affected with bunt, the lower two broken in halves to expose the smut spores. (a to c after Humphrey and Potter.) d. Spores of wheat bunt slightly magnified. e. to g. Germination of spores of wheat bunt.

LOOSE SMUT

Caused by *Ustilago tritici* (Pers.) Jens.

In Texas, loose smut of wheat is more important than bunt. A conservative estimate of the crop loss* from this disease is shown in Table 1.

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*The estimates of losses in Texas of cereal diseases and as presented in Table 1 is taken from the Plant Disease Bulletin, Supplement 4, June 20, 1919, of the United States Plant Disease Survey, of which the present writer is collaborator.

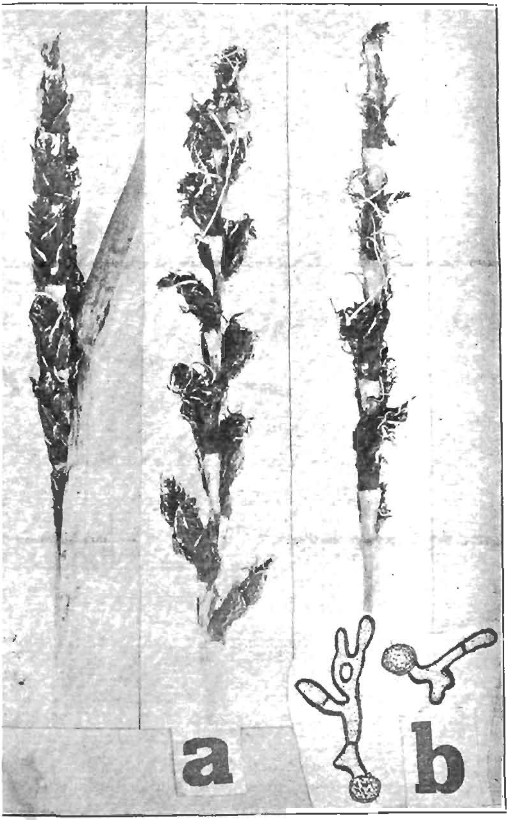

FIGURE 2.

a. Three wheat heads affected with loose smut. b. Germination of loose smut spores.

Symptoms. Loose smut of wheat may be readily recognized in the field as it usually becomes noticeable when the heads are being formed. At that time, infected heads are covered with a loose, black, sooty powder which falls away when the stalk is even slightly shaken by the wind, and leaves the center axis of the head practically bare (Fig. 2, a). It is during this time that the loose smut spores are readily blown about by the wind to the neighboring wheat heads, many of which are in bloom. These spores lodge between the glumes or chaff and germinate (provided weather conditions are favorable) by sending out a germ tube (Fig. 2, b) which penetrates the young ovaries. When mature, infected grains cannot be told from sound ones. The following season when these seeds are planted, the smut fungus within the kernel resumes activity during its germination, growing within the young plant, and keeping pace with it until blossoming time, when it starts again its life cycle.

Control. The fact that infection becomes established at an early stage within the developing wheat grain, makes control measures somewhat more difficult, since exterior treatment with chemicals cannot reach the fungus, which is now located within the interior of the grain. Loose smut of wheat is nevertheless amenable to treatment (see p. 30).

FLAG SMUT

Caused by *Urocystis tritici* Koern.

Flag smut is a new disease in the United States. Fortunately, however, this disease is not known as yet to occur in Texas. Every effort should, therefore, be made to prevent its introduction to this State. Flag smut is prevalent in Australia, whence it was introduced with the 5,250,000 bushels of wheat that were imported in 1917. The United States Department of Agriculture reports that this wheat has been unloaded in six American ports namely, Los Angeles, San Francisco, Portland, Seattle, Baltimore, and New Orleans. Two years later flag smut was found in Illinois. It is very likely that some of the wheat was shipped from New Orleans to Galveston; with a strong probability, however, that this wheat has been used for milling purposes and was not used for sowing. However, because of this uncertainty, every effort should be made to determine whether or not flag smut is present in Texas, and if so, no effort should be spared to stamp it out at an early date.

Symptoms. This disease is a typical leaf smut, making its appearance early when the plants are young. Infected leaves become somewhat twisted (Fig. 3, a to d), and covered with blisters (Fig. 3, e) which soon break open and allow the spores to escape (Fig. 3, f). After this the infected leaves split and tear into shreds. The flag smut does not seem to attack the heads, but, nevertheless, infected plants are so stunted (Fig. 3, b and c) as to fail altogether to produce normal heads. As far as is known, the spores of flag smut are carried with the healthy seed, upon which it clings. This is evident from the fact that the spores from infected leaves are blown to the healthy heads as they ripen in the field. Infection takes place early when the *planted seed in the soil begin to germinate.* In this way, likewise, the

soil becomes infected and it is possible for the spores of flag smut to remain alive there for several years. The Division of Plant Pathology and Physiology of the Texas Experiment Station urges our wheat growers to send us any suspicious specimens for examination.

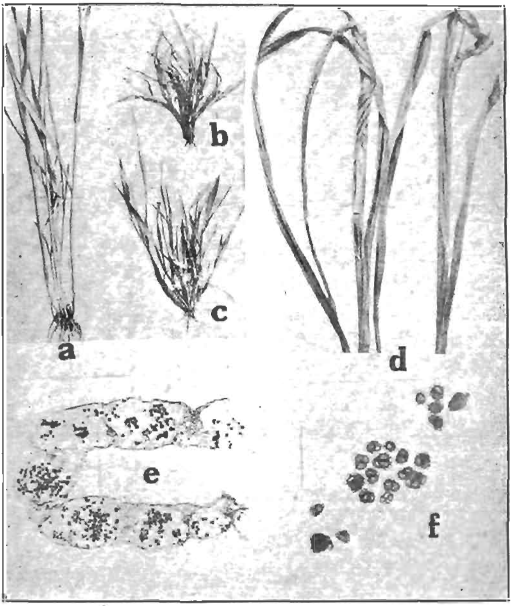

FIGURE 3.

a. Healthy wheat plant. b. and c. Stunted wheat plants due to flag smut. (a. and c. after Humphrey and Johnson.) d. Wheat plant curled at the top due to flag smut injury. e. Cross section of wheat plant to show spores of flag smut in host tissue. f. Magnified spores of flag smut. (d. to f. after McAlpine.)

"TAKE ALL"

Caused by *Ophiobolus graminis* Sacc.

Like flag smut, "take all" is a new disease which was introduced at the same time as flag smut. This trouble also came from Australia in 1917 with the five and one-quarter million bushels of Australian wheat that was unloaded in the six American ports above mentioned. "Take

all" has been discovered in Illinois, but as far as is known, has not, as yet, been found in Texas. For the reasons mentioned under flag smut, it is probable, however, that it is present in this State. Anyhow, the failure so far to detect its presence should not cause the people of Texas to relax their vigilance.

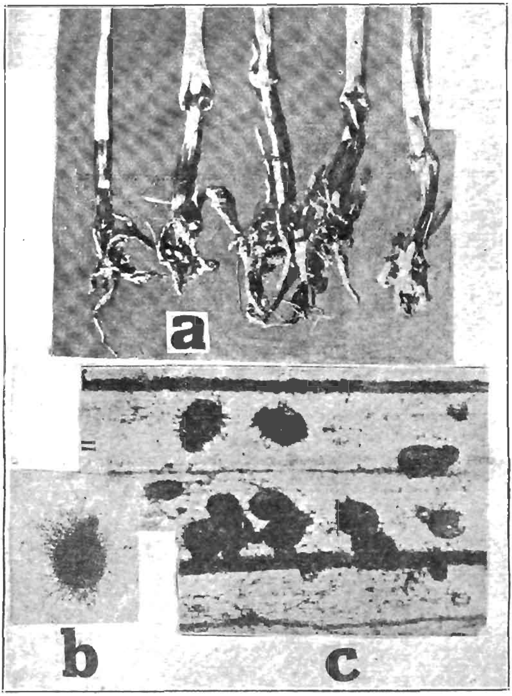

FIGURE 4.
a. Wheat plants affected with "take all." (a. after Smith and Mackinnon.)
b. and c. Pycnidia of *Ophiobolus graminis.*

Symptoms. The symptoms of "take all" vary with the seriousness of the attack. According to Humphrey and Johnson* the disease occurs

in patches which vary in size. Infected plants in these patches are greatly dwarfed and bluish-green in color in contrast with the normal green of healthy plants. The patches may vary from a few feet in diameter to seventy feet or more. Lastly, infected plants in these patches dry up and become decidedly brown at the stalk ends (Fig. 4, a), upon which are formed the spore sacs (Fig. 4, b and c) of the fungus. Before dying, some of the dwarfed plants attempt to recover and produce new shoots, thus taking on the appearance of a rosette. This rosette stage is in fact a characteristic symptom of "take all." As in the case of flag smut, it is urged that every suspicious specimen of "take all" or of any other wheat diseases should be sent in to us for identification.

WHEAT NEMATODE

Caused by *Tylenchus tritici* (Stein.) Bastian

Nematode is a wheat disease which is known to occur in Europe. In the United States the trouble has been found in California, New York, West Virginia, Virginia, and Georgia. Observations to date have not as yet established its existence in Texas. Every effort should be made to keep it out of this State.

Symptoms. In the field, the disease is usually noticeable on the heads, although it may also attack all parts of the plant (Fig. 5, a) except the roots. According to Fromme* the diseased heads remain green longer, ripen very late, and are also smaller than the sound ones (Fig. 5, b and c). In place of normal wheat grains (Fig. 5, e), hard galls (Fig. 5, d), which are smaller than the normal wheat grains, are found in the affected head. These little galls may often be mistaken for bunt, or stinking smut. In breaking open one of the galls and placing bits of it under the microscope, one will see, instead of the contents of the normal grain, innumerable small larvae of motionless young nematodes (Fig. 5, f). These are minute parasitic worms which are directly the cause of the trouble. When infected wheat is planted, the nematode worms leave the galls, and float around in the soil until they reach a sprouted wheat plant. Here apparently the roots are uninjured, as the little worms climb up to the parts of the plant above ground and penetrate the leaves nearest to the soil. As the plant advances in growth, the worms migrate from leaf to leaf, causing them to become distorted, and finally to the heads of the wheat plants (Fig. 5, b). There they enter the young kernels and produce the galls within which they mature, and lay their eggs. These eggs in turn, hatch and give rise to new broods of larvae. At maturity of the plant, the larvae become dried and motionless in the affected kernels, but take back new life when the grain is planted in the soil. For methods of control, see p. 32.

*Fromme, F. D. The nematode disease of wheat in Virginia, Va. Agr. Expt. Sta. Bul. 222, 1919.

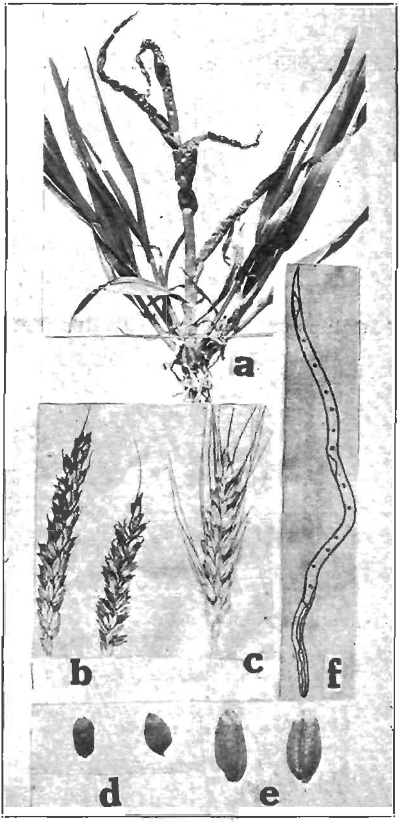

FIGURE 5.

a. Wrinkled and distorted condition of wheat leaves affected with the nematode disease. (a. and b. after Fromme.), d. Wheat grains affected by nematodes. e. Healthy grains for comparison. f. *Tylenchus tritici* (after Coleman and Regan).

ANTHRACNOSE

Caused by *Colletotrichum cereale* Manns

Anthracnose is quite common in Texas but not especially serious, since it usually attacks the wheat when it is practically mature. The same is also true for the oats and rye. It is, however, serious on Sudan grass (see p. 22).

Symptoms. The disease attacks all parts of the plant except the root. It causes cankers on the stems, spots on the leaves, and early ripening and shriveling of the grain in the heads. The causal fungus is carried over from year to year in the shriveled grain or on the straw from the infected wheat that is left in the field.

Control. Seed suspected of coming from infected localities should be screened and fanned before being planted. All the shriveled grains, instead of being wasted by burning, should preferably be boiled and fed to chickens or stock, while the healthy grain should be treated with formaldehyde as for bunt of wheat (see p. 30).

WHEAT SCAB

Caused by *Fusarium roseum* Lk.

This disease is of minor importance in Texas, although it is quite serious in other States.

Symptoms. Scab causes the grain to shrivel and to ripen early. Infected kernels are finally covered with a white-gray-to-pink mold growth. The same trouble attacks not only wheat, but also rye, oats, and corn.

Control. The only means known for controlling this disease consists in using sound, healthy grain from which the shriveled and diseased seeds have been carefully fanned and screened out. Where scab is prevalent, neither corn, wheat, or rye should be used in the same field as rotation crops. After carefully removing the shriveled kernels, one should treat the grain with formaldehyde in the same way as for wheat bunt (see p. 30).

BLACK STEM RUST

Caused by *Puccinia graminis* Pers.

This disease is quite prevalent in Texas and causes considerable losses to the wheat crop. The same disease also attacks oats, barley, rye, and a number of wild grasses.

Life Cycle. In the northern States, black rust starts on the common barberry *Berberis vulgaris* (Fig. 6, h) in the spring, forming the fruiting stage known as the cluster cup, so called because the spring spores of the wheat-rust fungus on the barberry are borne in yellowish, cup-like bodies. The spores in the cluster cup are known as Aeciospores. From the barberry, the cluster-cup spores are carried to the wheat by the wind, infection resulting in the red rust, or summer stage, so called because the spore pustules have a reddish tinge. Late in the season the red spore stage, also known as uredospores (Fig. 6, a), is followed by the winter or black rust stage (Fig. 6, b), also known as teleutospores (Fig. 6, c). These teleutospores winter over in a dormant

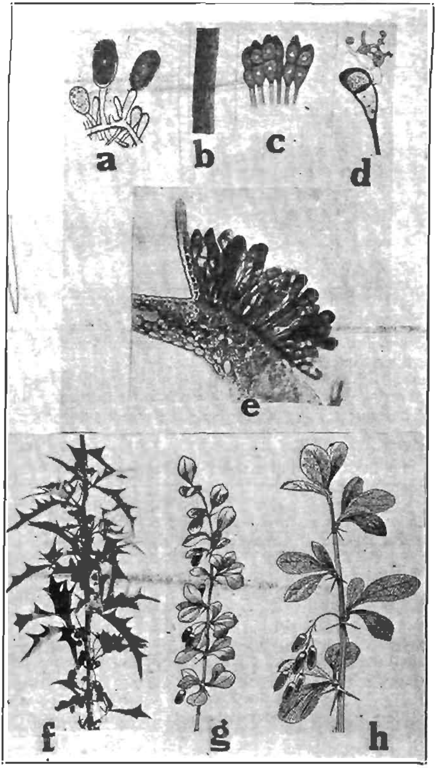

FIGURE 6.

a. Uredo or red-rust summer spores. b. Wheat straw showing black stem rust satge. c. Teleutospores. d. Germinated teeleutospore (a. to d. after Stakman). e. Cross section through wheat stem to show relationship of fungus to host (e. after Smith and Macklnnon). f. *B. trifoliata.* g *B. thunbergii.* h. *B. vulgaris.*

germinate (Fig. 6, d), but their sporidia are incapable of infecting the wheat and are carried back by the wind to the common barberry, where the cluster-cup stage is started anew. In Texas, the teleutospores after wintering over* are unable to germinate in the spring; hence they are no factor in infecting the barberry. The wheat rust then apparently perpetuates itself through the red-rust stage, or uredospores (Fig. 6, a). In Texas, the teleutospores seem to possess no particular significance, since they do not infect the common barberry *B. vulgaris,* consequently, the latter is not an enemy to the wheat. The vigorous campaign, recently started in the northern States to eradicate the barberry, is well justified there. In Texas, however, such a campaign is hardly warranted. Unless future research should prove otherwise, we are justified in believing that the black wheat rust in Texas is not dependent on the common barberry for its existence. Furthermore, the barberry which is most common in Texas (Fig. 6, f) is *B. trifoliata,* which, as far as is known, does not seem to harbor the cluster-cup stage of the wheat rust. In Texas this barberry is abundant where wheat is of little or no economic importance (Fig. 7, x and y). The common barberry, *B. vulgaris,* is, according to Professor H. B. Parks, Apiculturist to the Texas Experiment Station, very scarce in this State. One should not hesitate to plant the Japanese barberry *B. thunbergii* for ornamental purposes, since it is definitely known that this species does not harbor the wheat rust.

Control. It seems that rust on wheat develops fairly late in the season and that early ripening varieties are therefore especially desirable. In order that the rust may be eradicated, many of the wild grasses which grow around fences and ditches should be destroyed by burning. This simple measure, together with a well-worked-out rotation will help to control rust. There is also a decided difference in the resistance of the various varieties to rust.

BLACK CHAFF

Caused by *Pseudomonas translucens* var. *undulosum* Smith, Jones, and Reddy.

This disease was first described by Dr. E. F. Smith† and is found in Texas to a limited extent. Fortunately, it has not as yet reached an epidemic form.

Symptoms. The effect of this disease is to dwarf the spikes and to shrivel the kernels, thereby reducing the yield. On the chaff, the disease appears as black, long, sunken stripes. The glumes become black-to-brown spotted and in the bearded varieties, the beards, too, take on the same color. In an advanced stage of the disease, the kernels are badly shriveled.

Control. Dr. Smith recommends the using of wheat seed from fields known to be free from black chaff. All shriveled wheat should be carefully fanned and screened out and the healthy seed treated with formaldehyde as for wheat bunt (see p. 30).

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*To germinate, the teleutospores must pass through the influence of a rigorous winter such as is common in the northern and western States.

†Smth, E. F. A new disease of wheat. Jour. Agr. Res., Vol. 10:51-53, 1917.

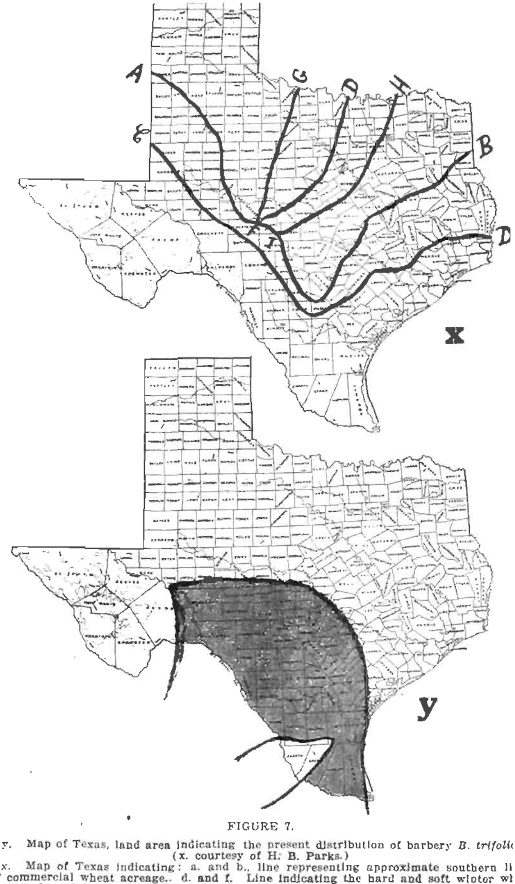

FIGURE 7.

y. Map of Texas, land area indicating the present distribution of barbery *B. trifoli*
(x. courtesy of H. B. Parks.)

x. Map of Texas indicating: a. and b., line representing approximate southern li of commercial wheat acreage. d. and f. Line indicating the hard and soft winter wl areas. h. and i. Line representing the eastern limit of hard wheat grown under fa able local conditions. g. and f. Line indicating western limit of local cultivation of wheat. The area between lines a. and b. and c. d. may offer conditions favorable to presence of small areas to wheat primarily for home consumption. The region south line c. d. is in the main unsuited to wheat culture. (x. courtesy of H. Bentam, form Agronomist to the Extension Department of the A. and M. College of Texas.)

SEPTORIA BLIGHT (GLUME AND LEAF SPOT)

Caused by *Septoria sp.*

Septoria blight is not as yet very serious in Texas. This disease is manifested by a yellowing and the premature dying of the leaves. On examining infected foliage one will find it to be covered with numerous minute black and brown specks which are scarcely visible to the naked eye. Each spot appears as a depression on the leaf, blade, or glume, and contains numerous spore sacs, pycnidia, in which the spores are borne. The use of clean seed and a well-worked-out system of rotation will help to control this disease.

DISEASES OF THE OAT

LOOSE SMUT

Caused by *Ustilago avenae* (Pers.) Jens.

Loose smut of oats is very common in Texas and occasions considerable damage. The money losses from this disease as shown in Table 1 are very high; most of these losses, however, may be totally prevented.

Symptoms. The symptoms of loose smut are quite similar to those of the loose smut of wheat (see p. 6). The dispersal of the ripe spores in loose smut of oats takes places during the time of flowering and before harvest time. These spores are entrapped between the hull and the mature kernel of the healthy oat heads. Hence, the spores of the loose smut of oats, contrary to the loose smut of wheat, are held on the outside of the kernel, and infection takes place during the germination of the outwardly infected seed. Infection is especially favored when the weather is warm during sowing time; however, a cold spell during planting will considerably reduce the amount of smut. For this reason the prevalence of oat smut is largely determined by weather conditions. For methods of control see p. 31.

COVERED SMUT

Caused by *Ustilago levis* (Kell. and Sw.) Magn.

Covered smut of oats differs from the loose smut in that the affected heads rarely shed their spores before harvest time. The dispersal of the spores and the infection of the sound oat grain takes place during harvesting and threshing. An infected head cannot be readily distinguished from a sound one; however, a careful examination will reveal the fact that the grains of the diseased heads are light and filled with a mass of black spores, hence in appearance differing little from bunt of wheat.

Control. Covered smut may be controlled with the dry formaldehyde method as described for loose smut of oats (see p. 31).

BLACK STEM RUST

The same as for wheat (see p. 13).

LEAF RUST

Caused by *Puccinia coronata* Cda.

This rust is very prevalent on oats in Texas. The stage most common is the uredospore or red-rust stage. Late in the season, the teleutospores, or winter spores, appear. The cluster-cup or spring stage commonly occurs on the buckthorn. However, as with the wheat

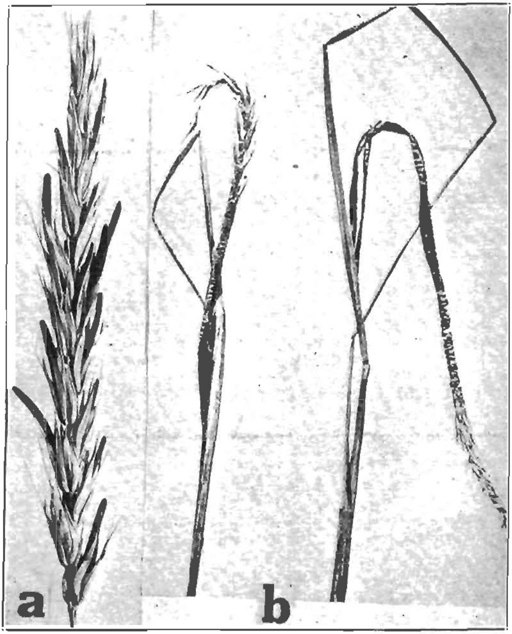

FIGURE 8.

a. Ergot of rye. b. Rye smut (b. after McAlpine).

rust, it is probable that the winter, or teleutospores, are not important in carrying over the disease and that the buckthorn is probably of little or no consequence. It is likely that the disease is carried over winter with the uredospores, or red-rust stage.

Control. The only method of control consists in growing resistant

varieties. The Texas rust-proof oats seem to answer the purpose very well in some seasons. Further selection from the Texas red-rust-proof oats for complete resistance to rust is still necessary. New varieties should also be introduced and tried.

DISEASES OF RYE

SMUT

Caused by *Urocystis occulta* (Wallr.) Rab.

This disease is commonly found in Texas and is usually confined to the stem and leaves, but is occasionally found on the heads (Fig. 8, b). On the leaves and stems it appears as long, narrow, dark-green stripes which break open and liberate dusty masses of dark spores. Frequently infected plants are dwarfed and when growing older tend to break and fall over. During harvesting and threshing, the spore masses from the infected parts of the plant are liberated and are scattered on the ripe kernels, or the spores may fall to the ground where they pass the winter. Infection takes place in the field during the germination of the seed. For method of control (see p. 30).

ERGOT

Caused by *Claviceps purpurea* (Fr.) Tul.

This disease is found in Texas, but as a rule, is not serious. It manifests itself in the head as large brownish-black bodies, which take the place of the rye kernels (Fig. 8, a). These bodies are very objectionable because they reduce the yield and make the rye unsafe for milling and unfit for use as stock feed.

Control. Grain containing ergot may be cleaned by being run through a fanning mill and then treated with salt brine to remove all the ergot which the fanning has missed. The salt brine is prepared in the same way as for wheat nematode (see p. 32). When the salt is dissolved, the rye is slowly poured in and vigorously stirred. All the ergot and light seeds will rise to the top and float, while the sound kernels will sink to the bottom. Everything that floats is then skimmed and destroyed by burning or boiling in hot water and fed to chickens. After the treatment, the salt solution is drained off and the rye rinsed in fresh water and allowed to dry as quickly as possible.

DISEASES OF THE BARLEY

COVERED SMUT

Caused by *Ustilago hordei* (Pers.) Kell. and Sw.

This disease is very prevalent in Texas and is of considerable importance. As with covered smut of wheat, the smut spores replace the entire content of the grain. Diseased kernels are thin and transparent, through which the greenish-black spore mass may be seen within (Fig. 9, a). The spores (Fig. 9, b) are not scattered about by the wind, and infection of the healthy grain does not take place until the membrane of the infected kernel is broken and this generally does not take place except during harvesting and threshing. The losses from covered smut of barley, as seen in Table 1, are considerable. For methods of control, see p. 30.

LOOSE SMUT

Caused by *Ustilago nuda* (Jens.) Kell. and Sw.

Loose smut of barley (Fig. 9, c) is prevalent in Texas. Like loose smut of wheat it is most noticeable in the field as the heads emerge from the "boot." In this case, the content of the kernels is replaced

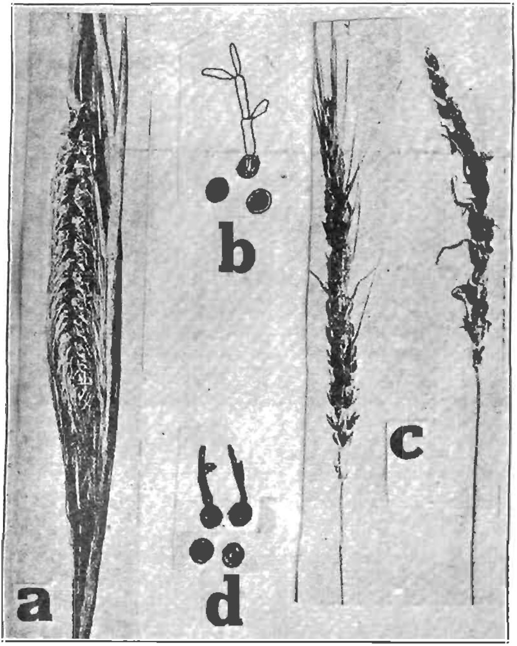

FIGURE 9.
a. Covered smut of barley. b. Spores, and germination of covered smut of barley. c. Loose smut of barley. d. Spores and germination of loose smut of arley.

by a dark sooty mass of spores which adhere loosely to the stem or rachis of the head. The mass of spores (Fig. 9, d) is not enclosed in an enveloping membrane except in the early stages, and this soon ruptures and disappears. The losses from loose smut for 1918 are shown in Table 1.

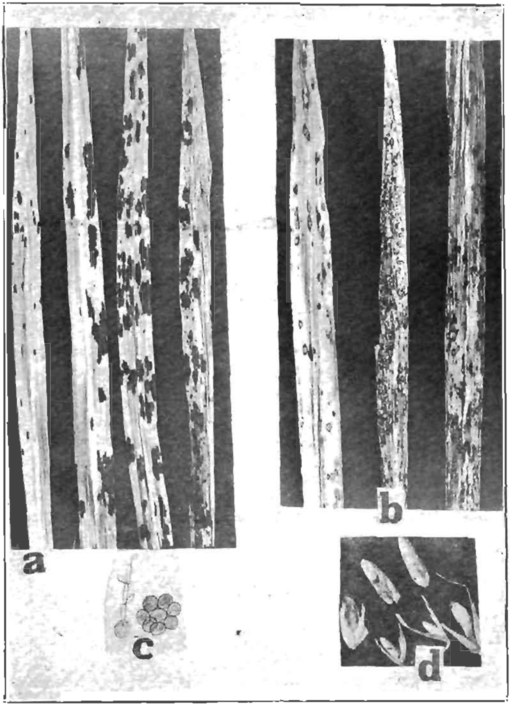

FIGURE 10.

a. Leaf blight of Sudan grass. b. Anthracnose on Sudan leaves. c. Germination of spores of Sudan smut. d. Healthy and diseased kernels of Sudan affected with smut. (d. after Melchers.)

DISEASES OF SUDAN GRASS

SMUT

Caused by *Sphacelotheca sorghi* (Lk.) Cl.

As far as is known, this disease has not as yet been found in Texas. This is perhaps due to the fact that Sudan grass is grown mostly for hay or pasture and not for seed. It is quite common in Kansas where it was recorded by Melchers.* The smut of Sudan grass is the same as the kernel smut of sorghums, which is common in Texas. Hence, it is very probable that the disease, if allowed, will attack the Sudan grass as it does sorghums. To enable our growers to recognize the disease, a brief description of it is here given. Diseased plants do not produce as large panicles as normal ones. The infected kernels are about twice the size of normal seed, but quite different in appearance (Fig. 10, d, and c). As far as possible, seeds of Sudan grass should be secured from sources known to be free from the disease and the crop grown not too close to sorghum fields.

ANTHRACNOSE

The same as for wheat, see p. 13 (Fig. 10, b).

LEAF BLIGHT

The same as for sorghum, see p. 28 (Fig. 10, a).

RUST

Caused by *Puccinia purpurea* Cooke

This disease has been very severe in Texas during the season of 1919 and is apparently favored by wet weather. During 1917 and 1918, rust was practically unimportant and it seemed to have been held in check by the dry weather of these two years. Rust is common in the southern States. It is also prevalent in the West Indies and in Central America. The Aecial, or cluster-cup stage, is unknown. Little is yet understood about methods of control.

DISEASES OF THE CORN

PHYSODERMA DISEASE

Caused by *Physoderma zeae-maydis* Shaw

This disease is known to be present in the eastern part of Texas, but it seems that the climatic conditions are such as to keep it more or less under check. The conditions most favorable for the spread of the disease are abundant moisture and fairly high temperatures before the plants are more than half-grown. Consequently, wherever such conditions prevail, the trouble is likely to break out in epidemic form.

Symptoms. According to Tisdale,† the disease occurs on the blade,

*Melchers, L. E. Smuts of grains and forage crops. Kans. Agr. Expt. Sta. Bul. 210, 1916.

†Tisdale, W. H. Physoderma disease of corn. Jour. Agr. Res., Vol. 16:127-154, 1919.

FIGURE 11.

a. and b. Blade and sheath of corn plant seriously spotted by Physoderma disease. (a. and b. after Tisdale.) c. Smut boil on ear corn. d. Germination of spores of corn smut. e. Rust on corn leaf.

sheath and culm of the corn plant. It is seldom found on the husks of the ears. Infection is usually abundant on the lower half of the plant. On the thin blades the spots resemble the early stages of corn rust (Fig. 11, e), that is, it is evidenced by slightly bleached to yellowish spots, which become dark within a few days. Frequently the spots are so numerous as to give the entire blade a rusty appearance (Fig. 11, a and b). On the mid rib of the blade, and on the sheath, the spots become considerably larger. During severe infection, the foliage shrivels and dies prematurely, after which the epidermis, or skin, over the infected areas becomes loose and brown-blistery. The dry epidermis finally breaks open and exposes the spores of the fungus, which are liberated as a brown dust. The culms are frequently completely girdled as a result of the disease, and the affected parts break during windy weather.

Control. No definite methods of control are as yet known for this disease. Tisdale recommends that in infected fields the old plants should be burned as soon as the corn has been harvested. However, a more desirable practice would be to plow under the old stalks as deeply as possible. Corn from infected fields may be used for silage. Crop rotation is also recommended.

SMUT

Caused by *Ustilago zeae* (Beck.) Ung.

Corn smut (Fig. 11, c) is characterized by smut boils on any part of the plant above ground. The spores of the fungus (Fig. 11, d) upon germination, are able to penetrate any part of the corn plant above ground as long as the tissue is young and tender. The smut boils when maturing burst open and liberate large masses of black dust which are made up of countless numbers of the spores of the causal fungus.

Control. Corn smut cannot be controlled by any form of seed treatment. All smut boils should be removed and destroyed by fire before they ripen and burst open. It is believed that if this practice could be carried out for a number of years by all the corn growers in the United States corn smut would eventually disappear. Infested corn stalks should not be thrown to the manure pile where the spores will remain alive during the winter and then be carried back to the land.

RUST

Caused by *Puccinia sorghi* Schw.

This disease is of little economic importance in Texas. It is found mostly on corn growing in lowlands. Rust attacks primarily the blade and sheath. It appears as rusty pimples (Fig. 11 c) on the infected parts. These later burst open and liberate a rusty powder which consists of the spores of the fungus. The disease is not important enough to warrant control measures.

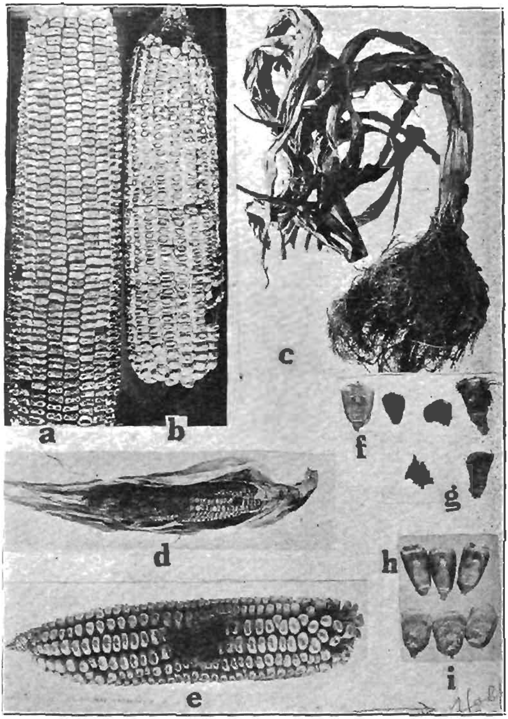

FIGURE 12.

a. Healthy ear corn. b. Ear corn affected by Fusarium rot. c. Corn plant killed by drouth. d. and e. Corn ears affected by black mold, at e. infection is seen to have originated at the place of injury from ear worm. f. Healthy corn grain from a corn ear affected by black mold. g. Five corn grains affected by black mold. h. Healthy corn grains. i. Three corn grains affected by Diplodia rot.

EAR ROTS

Caused by *Fusarium sp.* and by *Diplodia zeae* (Schw.) Lev.

Both of these rots (Fig. 12, a, b, f to i) are fairly common in Texas and are usually found on corn which has been left out in the field too long and the ears of which have been damaged by rain or insects. Care in harvesting and preventing the ears from being unnecessarily exposed to bad weather conditions will greatly check these troubles.

EAR MOLD

Caused by *Aspergillus niger* Van Thiegh. and *Aspergillus flavus.*

Both of these molds are very common in Texas, especially during dry weather. To the layman, the disease is erroneously known as smut because of the smutty appearance of the infected ears (Fig. 12, d to g). This is misleading, however, and the term mold is more appropriate. From recent investigations by the writer* it has been proved that both *A. niger* and *A. flavus* can attack the corn ear only at its milky stage. Infection in this case is favored by the corn ear worm or by other insects. Ear mold does not affect mature corn nor does it spread in the corn crib. Hence, any method which would tend to control the damage from the earn worm will also control ear molds. In this connection, selections should be made of corn varieties which possess well developed shucks. This will serve as a protection to keep out worms. Varieties with pendent ears will keep out rain water. Corn ear mold may also attack sorghums (Fig. 13, g and h). In this case insect injury in the field, as is the case with corn ear mold favors infection. Investigations during the last fifteen years by the Division of Agronomy of the Texas Experiment Station, have shown that sorghum mold in the field is more severe on varieties which are lacking in length of the peduncle. Selections made in this direction have resulted in better grain sorghums, seeds of which the Division of Agronomy is now ready to distribute to farmers of Texas. When sorghum heads are cut too green and shipped in cars with insufficient ventilation the damage from mold is bound to be severe.

Corn in Texas is often considerably injured by root rot, which is caused by the same fungus that induces scab in wheat, see p. 13. The remedy recommended for this disease is the same as for wheat: namely, corn should not follow corn, and wheat should not follow corn in localities where the disease is prevalent.

DROUGHT INJURY

Corn is very sensitive to drought. the injury from which (Fig. 13, c) is often spoken of as firing. It is true that we have no power to regulate rainfall, but it is within our power to conserve the soil moisture for the crop. Our Texas growers are urged to keep in touch with the Agronomy Division of the Texas Agricultural Experiment Station for the latest and best methods of conserving soil moisture.

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*Results of investigations by the Division of Plant Pathology and Physiology of the Texas Agricultural Experiment Station, on corn ear mold, will soon appear

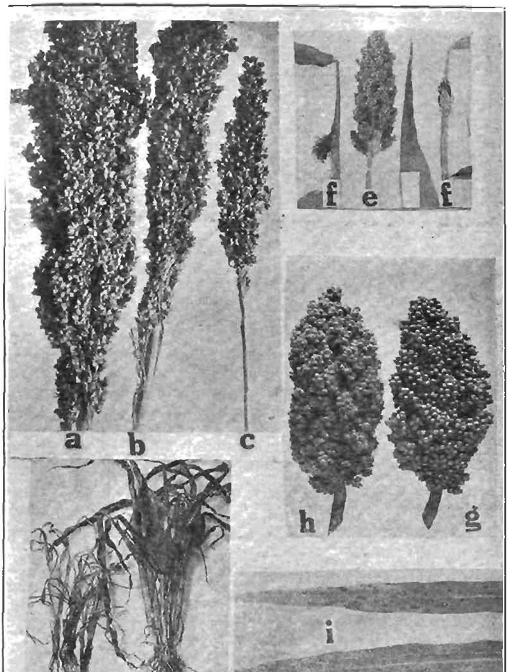


FIGURE 13.

a. Healthy sorghum head. b. and c. Sorghum heads affected by kernel smut. d. Healthy and diseased sorghum plant killed by alkali in the soil. e. Healthy sorghum head. f. and f. Two sorghum heads affected by head smut. (f. after Evans.) g. Healthy sorghum head. h. Sorghum head affected by black mold. i. Millet leaf spot.

DISEASES OF THE SORGHUM

HEAD SMUT

Caused by *Sorosporium reilianum* (Kuehn) McAlp.

This smut is very prevalent in Texas, especially in the Panhandle. It differs from the kernel smut in that it affects the entire head. Affected sorghum heads become a mass of smut (Fig. 13, e and f) which is somewhat similar to the smut of corn. It is fortunate that milo is not subject to the attack of this smut. Kaffir and broom corn are very susceptible to the head smut, but it is not so serious with the sorgos, which, however, are subject to the attack of kernel smut. This disease, like the smut of corn, cannot be controlled by any sort of seed treatment. The remedy would consist in avoiding continuous cropping of the susceptible varieties of sorghums, cutting out and burning affected heads, and avoiding seed from infected fields.

KERNEL SMUT

Caused by *Sphacelotheca sorghi* (Lk.) Cl. and *Sphacelotheca cruenta* (Kuhn) Potter

Of the many sorghums, kaffir and broom corn are especially subject to this disease. Kernel smut (Fig. 13, a and b) is also the same that attacks Sudan grass in Kansas. Infected heads bear a great number of false kernels. These are filled by a mass of smut dust which is enclosed in a cone-like, tough, grayish-brown membrane. The infected kernels readily break during threshing, in which case the spore masses are liberated and are smeared over the healthy ones. Infection with kernel smut of sorghum, therefore, occurs during the germination of the seed in the field. At that time, too, the spores which cling to the exterior of the seed coat germinate and penetrate the young seedlings. For method of control, see p. 32.

BLIGHT

Caused by *Bacillus sorghi* Burr.

This disease is very prevalent on sorghums in Texas. It also attacks Sudan grass (Fig. 10, a), as well as such weeds as the Johnson grass. The disease appears as irregular-shaped, elongated red blotches, which occur on the leaves and frequently on the stalks. In severe cases the roots also become infected. The only remedy recommended for this disease is to practice a rotation of such crops as are known to be free from the disease.

ANTHRACNOSE

Caused by *Colletotrichum falcatum* Went.

This disease is frequently found in Texas. It is characterized by definite gray to thin-colored spots, the latter of which are limited by a dark-reddish to brown ring. Late in the season, the center of the spot becomes covered with minute specks which consist of the fruiting bodies of the causal fungus. The disease is usually not serious enough

ALKALI INJURY

Young sorghum is sensitive to alkali in the soil. This form of injury usually appears in spots and is recognized by the yellowing and stunting of the plants (Fig. 13, d). Alkali injury is more frequent during dry weather, and on low, poorly drained spots in the field. Control measures lie mainly in the direction of proper drainage.

DISEASES OF THE MILLET

KERNEL SMUT

Caused by *Ustilago crameri* Korn.

Millet is frequently attacked by kernel smut. Infected kernels are filled with a mass of black spores which are enclosed by a thin membrane. During threshing, these smut balls readily break open so that the spores are scattered and cling to the seed. The disease may be controlled in the same way as the kernel smut of sorghum (see p. 32).

LEAF SPOT

Caused by *Piricularia grisea* (Cke.) Sacc.

This disease, although prevalent, is not very serious in Texas. It occurs on the lower leaves as spots which are dark-purple or reddish, later becoming black and finally straw-colored. The border of the spot is limited by a black-to-purple ring (Fig. 13, i). Badly infected leaves gradually turn yellow, dry up, and shrivel, thus reducing the yield indirectly. This disease is not sufficiently important to warrant methods of control.

RICE DISEASES

A discussion of the diseases of rice is here omitted. Owing to the importance of the rice crop in Texas, it is felt that its diseases could be advantageously treated in a separate bulletin.

CONTROL METHODS FOR SMUTS

Since the control methods for smuts are different from those required for other diseases, it is necessary to consider these separately. Smuts, with but few exceptions, are kept in check by the formaldehyde or hot water treatments. Formaldehyde is a fungicidal gas which has been dissolved in water. It is sold by all drug stores as 40 per cent pure. In purchasing it, one should not accept weaker solutions as substitutes. Formaldehyde acts through its gas fumes by killing the fungus spores which adhere to the exterior coat of the grain. The fumes are irritating when inhaled, hence one should be careful when handling this chemical. Seed which has been treated with formaldehyde, and dried, is fit both for human and stock feed. This is merely mentioned so that no fear need be entertained when treated grain is accidentally eaten by stock or poultry.

TREATMENTS FOR COVERED SMUT OF WHEAT, OATS, AND THE SMUT OF RYE

As already mentioned on p. 5, germination and the penetration of the spores of covered smut in wheat and oats take place in the field during the germination of the wheat or oat grains in the field as they carry the fungus spores which cling to the exterior of the seed coat. It becomes, therefore, evident that treatment is necessary to kill the spores, and thus prevent their germination. There are several methods of treatment.

(1) *Formaldehyde Treatment.* The wheat, oat, or rye seed before treatment should be thoroughly cleaned and fanned. The formaldehyde may be applied in the following ways:

a. *Soaking Method.* With this method, the grain is soaked for ten minutes in a solution made up of one pint or pound of 40 per cent. formaldehyde diluted in 40 gallons of water. During this time the grain is placed in half barrels and thoroughly stirred and all the floating material is skimmed off. After the treatment, the formaldehyde is drained off and the seed spread out to dry quickly. The soaking method is not very popular with farmers. With this method one pint or pound of formaldehyde will be sufficient to treat 50 bushels of grain.

b. *Spraying Method.* With this method the grain to be treated is sprayed with a solution of one pint formaldehyde in 40 gallons of water. The spraying is done with an ordinary garden sprinkler (Fig. 14, a) while the grain is being shoveled from one place to another. It will require about one gallon of the solution for each bushel of grain. After the seed has been thoroughly wetted, it is piled up in a heap and covered with a heavy blanket or canvas for 8 to 12 hours. After this treatment the grain is spread out thinly and allowed to dry as quickly as possible. As soon as it is sufficiently dry to run through the drills it may be planted.

TREATMENT FOR LOOSE SMUT OF WHEAT AND THE COVERED SMUT OF BARLEY

The above smuts may be kept in check by the use of hot water, known as the "long-soak" method, the details of which are as follows: The seeds are simply soaked for three hours in hot water which is maintained at a temperature of 110 to 115 degrees F. This method is somewhat tedious, and much time is saved by treating seed on a large scale. In this connection, county agents will find it advisable to have several farmers combine and treat their seed together. The seed to be treated is placed in a sack. Two iron tubs or kettles are maintained on two separate fires, and the temperature of the water in both is maintained at 110 to 115 degrees F. In one of these kettles, the sacked grain is now placed, and stirred so that all the seed is wetted and covered by the hot water. The temperature should be closely watched, and if it rises above 115 degrees F., cold water is slowly poured in. If it falls below 110 degrees, hot water is added from the second kettle. After a little experience, considerable skill will be developed in keeping up a slow fire, which will maintain the proper temperature. It goes without saying that two ordinary thermometers

are indispensable in this treatment. As the range of temperature from 110 to 115 is small, but higher than the average daily temperatures, the thermometers should be roughly tested for accuracy before use. *After the treatment, the seed should be quickly dried. This method,* if carefully carried out, will result in no injury to the germination of the seed.

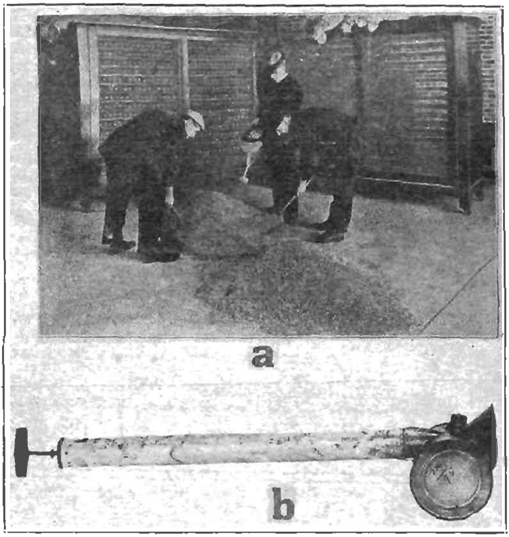


FIGURE 14.

a. Showing method of treating wheat with formaldehyde, which is applied with an ordinary garden sprinkler. b. *Hand atomizer used to apply formaldehyde by the Haskell method.*

CONTROL OF LOOSE SMUT OF OATS

The Haskell or Dry Method. With this method the treatment is very much simplified. As the seed is being shoveled from one heap to another, each shovelful is sprayed with a solution consisting of one pint of 40 per cent. formaldehyde in one gallon of water. This solution is used at the rate of 1 quart to each 50 bushels of seed. A small quart sprayer (Fig. 14, b) is very convenient for this purpose. With this treatment, all that is necessary is not to wet the seed but merely *to moisten it with the formaldehyde solution.* After the oats are all

treated, they are piled in a heap and covered with a blanket, canvas, or sacks to confine the formaldehyde vapors in the grain pile. At the end of 5 hours, the seed should be uncovered and will then be ready to plant. The chief advantage of the so-called dry method over the wet method as described for the wheat, is that it makes it possible to plant the seed immediately after the disinfection is completed. Moreover, with this method of treatment, the oats do not swell, hence they require no drying and do not stick to the drill. The operation is simple; the treatment effective and does not injure the germination, if directions are properly carried out. The Haskell method is not generally used against bunt of wheat, where the formaldehyde wet method see p. 30 is preferred. The Haskell method, however, is recommended for the loose smut of oats; it is also effective for treating rye seed against smut. It is thus seen that with rye, either the Haskell dry method (see p. 31), or the wet method (see p. 30), is equally effective.

TREATMENT FOR SORGHUM SMUT

With sorghums, only the kernel smut is amenable to treatment.

a. *Formaldehyde.* The seed to be treated are soaked for two hours in a solution made up of one pint of formaldehyde in 30 gallons of water. After treatment they are spread out to dry quickly.

b. *Hot Water.* Kernel smut of sorghum may also be controlled by soaking the seed 10 to 12 minutes in hot water, the temperature of which is maintained at 142 degrees F. After the treatment the seed should be spread to dry quickly.

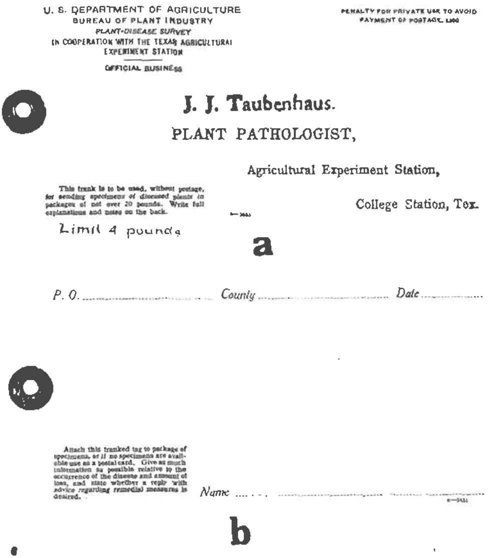
Where Treatment Is Unsuccessful. Inquiries are frequently received by the Division of Plant Pathology for directions as to treating corn seed for smut and sorghum seed for head smut. As far as is known, neither of these two smuts is amenable to treatment, either by hot water method or with formaldehyde. Control methods for corn smut, and head smut of sorghum consist chiefly in cultural practices as shown on pages 24 and 28.

Control for Wheat Nematode. It goes without saying that nematode disease should be prevented from being introduced in Texas. Suspected wheat should be carefully examined for the galls. This is feasible in examining the screenings. If no galls are found, the seed may be used with safety. If, however, galls are found, the wheat should not be used for seed unless it has been carefully fanned and given the salt-brine treatment. This treatment, which aims at eliminating the galls by floating them off, is as follows: Four pounds of common salt are dissolved in 25 gallons of water. Large tubs or barrels may be used for this purpose. In this liquid the wheat is slowly poured, vigorously stirred; and all trash, light seeds, and galls are carefully skimmed off as they rise to the surface. After the skimming, the salt solution is drained off to another container, and the seed are rinsed in pure water and spread out to dry quickly. The same salt solution may be used over and over again until exhausted. All the skimming that comes off should be burned or boiled in hot water in order to destroy the nematode worms within, after which it may be fed to poultry or stock.

DIRECTIONS FOR SENDING IN DISEASED SPECIMENS OF PLANTS

Statements Following Specimens. All inquiries relating to diseases of plants, in order to receive immediate attention, should be addressed to the Division of Plant Pathology and Physiology. Wherever possible, diseased specimens should be accompanied by the following brief statements:

1. The seriousness of the disease, the time of its first appearance, and how fast it is spreading.



U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
PLANT-DISEASE SURVEY
IN COOPERATION WITH THE TEXAS AGRICULTURAL EXPERIMENT STATION
OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE TO AVOID PAYMENT OF POSTAGE, $300

J. J. Taubenhaus.
PLANT PATHOLOGIST,
Agricultural Experiment Station,
College Station, Tex.

This frank is to be used, without postage, for sending specimens of diseased plants in packages of not over 20 pounds. Write full explanations and notes on the back.

Limit 4 pounds

a

P. O. .... County .... Date ....

Attach this franked tag to package of specimens, or if no specimens are available use as a postal card. Give as much information as possible relative to the occurrence of the disease and amount of loss, and state whether a reply with advice regarding remedial measures is desired.

Name ....

b

FIGURE 15.

a. and b. Facsimile of government franked tags which may be used in sending specimens of diseased plants by mail and without postage.

2. The various field symptoms of the disease.
3. Climatic conditions, the nature of the soil, method of culture, and the system of rotation practiced.
4. Remedies tried.

Quantity of Diseased Material. Wherever possible, large quantities of diseased material, but not over four pounds, should be sent in. The plants selected should be those that exhibit the disease in its [illegible]

Soil. The Division of Plant Pathology does not make chemical analyses of soil. Such analyses are not necessary, but when desired should be sent to the State Chemist.

How to Send Diseased Specimens. As far as possible, diseased seedlings or plants should not be enclosed in letters. They usually dry up badly and break with the handling at the post office. Wherever possible, young seedlings, tender shoots or leaves, should be wrapped in the regular waxy shipping paper, such as is used by all florists. Where this is not on hand, ordinary newspaper may be used instead. A snug package should be made and tied securely before mailing. Diseased fruits, fleshy roots or tubers, or diseased limbs should first be wrapped in ordinary newspaper and then placed in a strong paper box. It is often well, in cases of fleshy roots or fruits, to perforate the sides of the box in order to allow the free access of air to the specimens. This precaution will prevent the rotting of the material by secondary invaders.

Ship Specimens by Mail. In order to insure quick delivery, specimens should be sent by mail. To save postage, which is often expensive, especially when shipping heavy material, one should use franked tags. These tags (Fig. 15, a and b) may be obtained by dropping a postal to Director Youngblood or to the Division of Plant Pathology and Physiology. If these tags are used, specimens not over four pounds may be shipped by mail without postage.

Co-operation Desired. The Division of Plant Pathology and Physiology respectfully asks the co-operation of every crop grower in Texas. Write and state your plant disease problems. All available information will be cheerfully and promptly given.